Microwave-activatable latent heat storage body

a. FIELD AND BACKGROUND OF THE INVENTION

The invention relates to a latent heat storage body having a paraffin-based latent heat storage material and to methods for producing a latent heat storage body.

It is known to use latent heat storage bodies to temporarily decouple the generation of heat or cold and subsequent consumption of heat or cold. They enable efficiency to be improved, in that the latent heat storage material contained in them stores heat during a phase transition, for example from solid to liquid, caused by the supply of heat, and is able to release heat during an opposite phase transition at a different time. The temporal decoupling of the supply and release of heat makes it possible to achieve long, continuous running times for heat or cold generators combined with high levels of efficiency and low start-up, shut-down and standstill costs. Latent heat storage bodies are used, for example, in installations for generating heat from solar energy or from fossil energy carriers, and also in cooling circuits. For the prior art, reference is made, for example, to PCT/EP93/03346 and PCT/EP98/01956, and to the further documents referred to therein. In particular, PCT/EP98/01956 has disclosed a latent heat body with paraffin-based latent heat storage material held in a carrier material which has holding spaces. In the known latent heat body, it is provided that the carrier material is assembled from individual support-material elements, for example by adhesive bonding, capillary-like holding spaces for the latent heat storage material being formed at least between the support elements. This arrangement leads to a latent heat body which is easy to produce and is highly effective, having a high heat storage capacity together with sufficient structural strength even in the heated state, and with carrier material which is as far as possible automatically filled with the latent

heat storage material. Depending on the selected dimensions and fields of use, the advantages of the abovementioned latent heat storage bodies, as well as other known latent heat storage bodies, are counterbalanced by the undesirably long time intervals which are required to supply or store thermal energy. Excessively long heating times result in particular when the thermal energy has to be supplied exclusively by means of thermal conduction from the surface into the interior of a latent heat storage body and if barriers to thermal conduction are present, which barriers may, for example, exist between sub-bodies which loosely adjoin one another inside a latent heat storage body.

Therefore, it has already been attempted to introduce microwave energy into latent heat storage bodies containing a large amount of paraffin as latent heat storage material and, in this way, to heat this material. It is known that microwaves are able to penetrate through bodies which are to be heated at very high speed and to heat microwave-active substances contained therein by exciting molecular vibrations by means of kinetic energy, without thermal conduction being required. Therefore, by heating a body by means of microwave radiation, it is in principle possible to achieve considerably shorter heating times compared to heat transfer by means of thermal conduction. However, a fundamental difficulty is that in industrial applications, microwave-passive substances, for example paraffin-based latent heat storage material, whose molecules cannot be heated, or cannot be heated to a sufficient extent for industrial application, by the microwave radiation, are frequently of importance in addition to microwave-active substances. While the microwave-active property of water and some carbon compounds is now assumed to be known, in many technical fields problems are caused by numerous other substances, e.g. cotton, some plastics, wood and

paraffins, having an insufficient or unforeseeable microwave activity. To solve this problem, microwave antennae, for example in the form of carbon, OH groups in the form of soot, glycerol or alcohols, are added to these substances. For example, in PCT/EP98/01956, which has already been referred to in the introduction, it is proposed for the latent heat body to contain a microwave-active substance, in particular from one or more of the groups of materials consisting of glass materials, plastics materials, minerals, metals, coal or ceramic. The result is that, depending on the arrangement or distribution of the microwave-active substance in the latent heat body, numerous heat nests are formed under the influence of microwave radiation, and because of the temperature difference which exists, these nests release their thermal energy to the adjoining paraffin-based latent heat storage material, which is predominantly microwave-passive. The shortened thermal conduction path in this way in principle leads to acceleration of the heating operation.

However, a general drawback of adding microwave antennae is that these added substances are frequently undesirable from a use aspect, require increased vigilance when they are used, may be irrevocably consumed or, for example, entail the risk of segregation and therefore dangerous differences in concentration, which may lead to local overheating and to a material composite comprising microwave-passive and microwave-active material being "burnt through". In general terms, therefore, the use and the range of applications of many microwave-passive materials has hitherto been restricted by the addition of microwave-active substances.

Even with latent heat storage bodies, for example in the case of heat cushions or panels, with a high level of paraffin as latent heat storage material, it has not hitherto been possible to achieve a satisfactory solution enabling microwave energy to be

introduced and, in this way, the latent heat storage body to be heated. Over and above the difficulties mentioned above, previous attempts were made more difficult by the fact that a high vapour pressure may build up in a hermetically closed enclosure for a paraffin packing containing, for example, a liquid microwave-active material, microwave-active substances can often only be incorporated separately from the paraffin in microencapsulated form, involving considerable technical outlay (metered extrusion), and this in turn requires relatively high levels with respect to the paraffin. However, over the course of time the microwave-active additions which have been incorporated in this way are also irreversibly volatilized or at least tend to appear. In turn, different layers of the microwave-active and/or the microwave-passive material lead to considerable temperature fluctuations. Overall, therefore, there are still considerable technical problems involved in the production, the use properties and the operational reliability of microwave-passive materials doped with microwave-active substances.

SUMMARY OF THE INVENTION

Therefore, working on the basis of the abovementioned PCT/EP98/01956, (WO98/53264) it is an object of the present invention to provide a latent heat storage body which can be heated by microwaves, contains a paraffin-based latent heat storage material and, compared to the body in the above document, is easier to produce, has more advantageous use properties and a higher operational reliability. A further part of the object consists of providing a simplified production method for a latent heat storage body containing a paraffin-based latent heat storage material. Moreover, the object includes providing a method for producing a latent heat storage body which can be heated by microwaves and contains a paraffin-based latent heat storage material.

According to the invention, the first part of the object is achieved by a latent heat storage body ~~having the features of Claim 1, advantageous configurations of which are given in Claims 2 to 21. In the latent heat storage body according to the invention~~ having a paraffin-based latent heat storage material, ~~it is provided that~~ the latent heat storage body containing ~~contains~~ a hygroscopic material or. The hygroscopic material has a pronounced capacity for taking up moisture from its environment and binding this moisture to itself.

Particularly suitable hygroscopic materials include calcium chloride ($CaCl_2*6H_2O$), iron chloride ($FeCl_3$), copper sulphate ($CuSO_4*5H_2O$), magnesium chloride ($MgCl_2*6H_2O$), potash (potassium carbonate, K_2CO_3), silica gel and numerous other substances.

The moisture may in particular be water-based liquid, including, of course, pure water, which can be taken up from the environment by a hygroscopic material even in the vapour phase, that is to say in gaseous form. The hygroscopic action is based partially on adsorption and, in addition to other - frequently subordinate - effects, in fine-pored materials, is also often based on capillary condensation. Furthermore, the hygroscopic action may also be based on the moisture being contained in the hygroscopic material as a salt solution (water of crystallization). The capillary condensation is important if the vapour pressure which is approximately described by the Gibbs-Thomson equation above a liquid surface which is concavely curved in the pores or capillaries of a body is reduced to such an extent that it becomes lower than the vapour pressure in the surrounding gas. By taking up moisture, in particular water-based moisture, according to the invention the hygroscopic material contained in the latent heat storage body brings about automatic doping of a relatively microwave-passive latent heat storage material with a highly microwave-active material, the

high efficiency of which is based on the extremely dipolar character of water. The inclusion of hygroscopic material allows the latent heat storage body according to the invention, which may, for example, be a paraffin-containing heat cushion, to be heated successfully in a standard domestic microwave. Furthermore, the hygroscopic material overcomes the difficulties which have previously been involved when the aim was to use water as microwave-active material, namely its extreme paraffin phobicity (segregation), its ready volatility and the associated increase in vapour pressure at elevated temperatures.

A further advantage is that after it has been heated or after the latent heat storage body has been used, the microwave-active moisture always returns to those locations in the latent heat storage body at which the hygroscopic material is contained in the latent heat storage body, and that the hygroscopic material has no tendency to become segregated from the latent heat storage material. In this way, in addition to automatic regeneration of the latent heat storage body through moisture uptake, the further advantage is achieved that the moisture always reproducibly adopts the originally provided distribution in the latent heat storage body, so that segregation and undesirable concentration differences are not possible. Consequently, local overheating of the latent heat storage body or "burning through" is effectively prevented, so that there is no risk of explosion or fire even in the event of the latent heat storage body being used incorrectly. Overall, therefore, the operational reliability of the latent heat storage body is also increased considerably compared to known designs.

Further advantages of the latent heat storage body according to the invention are that the thermal conductivity is also increased considerably on account of the content of water of crystallization and the

extremely finely distributed condensation water, so that for the first time it is realistically possible to achieve greater layer thicknesses. Moreover, there is no need to apply a vacuum with a view to achieving the hygroscopic properties, and there is no risk of leaks. The latent heat storage body according to the invention is also distinguished by a particularly great versatility, since in addition to the preferred option of heating by microwaves, as an alternative or in addition heating may also take place using conventional methods, for example in a water bath or in an oven. An additional advantage of heating by microwaves is that only minimal outlay on energy is required, since the microwave energy can be introduced very efficiently into the moisture bound in the hygroscopic material, in particular including into the water of crystallization. In addition, numerous hygroscopic materials are very inexpensive and are also relatively or even altogether non-toxic, and in many cases do not cause any chemical change to the paraffin-based latent heat storage material.

In a preferred possible configuration, the latent heat storage body is held in a sheath which is permeable to vapour diffusion and may, for example, be a film which at its edges or connecting regions and/or within surface regions has openings which are permeable to vapour diffusion and lead to the environment surrounding the latent heat storage body. In this "open system", vapour exchange takes place between the interior of the latent heat storage body and its surrounding environment, so that moisture which is present in the environment can be taken up by the hygroscopic material contained in the latent heat storage body. If the latent heat storage body is irradiated with microwaves, this leads to heating and subsequent evaporation of the microwave-active moisture, in particular water, stored in the hygroscopic material. At the locations where it is

formed, the heated steam is in direct and immediate heat exchange with the adjoining heat storage material, with the result that the latter can also be heated within a short time. The evaporation of the moisture emerging from the hygroscopic material leads to an increase in the volume of the microwave-active moisture, so that the volume of the latent heat storage body enclosed in the sheath also rises. The pressure which is formed in the sheath in this way allows some of the vapour to escape from the sheath which is permeable to vapour diffusion into the environment, so that it is advantageously possible to prevent the sheath from being destroyed by an unacceptably high internal pressure. The heated latent heat storage body can then be supplied for its intended use. The loss of moisture from the latent heat storage body as a result of at least some of the vapour escaping is automatically compensated for by the fact that the hygroscopic material contained in the latent heat storage body binds the moisture which is still present to itself as cooling of the latent heat storage body progresses, and a vapour pressure drop leads to ambient moisture flowing back through the openings in the sheath, which are permeable to vapour diffusion, into the interior of the latent heat storage body until an equilibrium is established as a result of a large quantity of moisture once again being stored in the hygroscopic material. In a further variant, the latent heat storage body may also be accommodated in a sheath which is impermeable to vapour diffusion, for example in a plastics film or aluminium foil (closed system). In this case, destruction caused by vapour pressure can be prevented, for example, by a suitable amount of spare material in the sheath, which may also consist of an expandable material, and/or by a suitably adapted quantity of moisture in the latent heat storage body. Furthermore, it is also possible for the hygroscopic material for its part to be accommodated in a sheath

which is permeable to vapour diffusion. In this case, the hygroscopic material together with this sheath may be separated from the adjoining latent heat storage material in such a manner that it is permeable to vapour diffusion, so that its surface cannot be passivated by liquefied paraffin.

The latent heat storage body according to the invention may have capillary spaces which open up paths to the hygroscopic material. By way of example, it is possible for the paraffin-based latent heat storage material to have a solidification structure which is modified by additives, in particular with cavities which are in the form of hollow cones, as described in PCT/EP93/03346.

This makes it possible to significantly improve the response of the latent heat storage material when heat is supplied. As a result, the paraffin-based latent heat storage material adopts, as it were, a porous structure. When heat is supplied, it is easier for constituents of the latent heat storage material which melt to flow through the hollow structures which are provided in the material itself. It is possible, if appropriate also in view of air inclusions which are present, for a type of microconvection to be established. This also results in a high mixing action. Furthermore, there are also advantages with regard to the expansion performance in the event of a phase change. The structural additive is preferably homogeneously dissolved in the latent heat storage material. In detail, structural additives such as those based on polyalkyl methacrylates (PA-MA) and polyalkyl acrylates (PAA) have proven suitable as individual components or in combination. Their crystal-modifying action is brought about by the fact that the polymer molecules are also incorporated into the growing paraffin crystals, preventing this crystal form from growing further. Because the polymer molecules are also present in associated form in the homogeneous solution

in paraffin, it is possible for paraffins to grow onto the special associates. Hollow cones which are no longer able to form networks are formed. Because of the synergistic action of this structural additive on the crystallization behaviour of the paraffins, cavities are formed and, as a result, the perviousness of the heat storage medium paraffin (for example to air or water vapour enclosed in the latent heat storage body or to liquefied phases of the latent heat storage material, i.e. the paraffin itself) is improved compared to paraffins which are not compounded in this way. In general terms, suitable structural additives include ethylene, vinyl acetate copolymers (E, VA), ethylene/propylene copolymers (OCP), diene/styrene copolymers, both as individual components and in a mixture, as well as alkylated naphthalenes (Paraflow). The proportion of structural additives starts at a fraction of a percent by weight, realistically at approximately 0.01% by weight, and presents distinct changes, in the sense of an improvement, in particular up to a level of approximately 1% by weight. The capillary spaces on the one hand make it easier for the hygroscopic material to take up moisture, in particular from the environment surrounding the latent heat storage body, and, on the other hand, following the evaporation of the moisture, assist with heat transfer to the latent heat storage material as a result of improved flow of the heated vapour through the latent heat storage body. Furthermore, to accelerate and make more uniform the heating of the latent heat storage body, it is preferable for the hygroscopic material to be disposed in distributed manner in the latent heat storage body.

With a view to the possibility of achieving a uniform and rapid flow of the microwave-active moisture through the latent heat storage body, the hygroscopic material preferably forms 5% or less by mass of a latent heat storage body, so that it is also possible

to achieve the desired, short heating times. The small amounts added, and also the small amount of microwave-active moisture which is required, therefore do not significantly reduce the amount of paraffin-based latent heat storage material, so that the volume-specific or weight-specific heat storage capacity is not significantly impaired. According to a preferred refinement of the latent heat storage body, this body contains hygroscopic material of differing efficiency. Very strongly hygroscopic materials can be used as "water extractors" and can be used in combination with less strongly hygroscopic substances which are more difficult to heat, as product, performance and temperature regulators in a latent heat storage body. The combination of hygroscopic material of differing efficiency enables moisture to be evaporated during heating over a range of temperatures which can be influenced by the composition of the material. In addition to high operating reliability, compared to sudden evaporation, this also results in more favourable heat transfer to the latent heat storage material.

According to another advantageous configuration of the latent heat storage body, the latter may have a carrier material with capillary-like holding spaces which hold latent heat storage material. In the first instance, consideration is given to forming the capillaries in such a way that the holding spaces have the effect of sucking in automatically, in particular with respect to the latent heat storage material. A latent heat storage body of this type is distinguished by a desired dimensional stability even with liquefied latent heat storage material, preventing the latent heat storage material from being sweated out. With regard to the microwave-active moisture which is additionally present and cannot be mixed with the latent heat storage material, in particular water, separation of the two components is also prevented.

Moreover, the bodies comprising carrier material and latent heat storage material, on account of their high specific surface area, together with the openings of the capillary holding spaces, act as condensation cores or nuclei for the vapour phase of the heated microwave-active material, which has a positive effect on the heat transfer from the vapour to the latent heat storage material. Furthermore, it is possible for the capillary-like holding spaces also to be adapted for a self-sucking action with regard to the microwave-active moisture.

Preferably, it is provided that the latent heat storage body contains a number of individual support-material bodies, which may be in platelet-like or grain-like form. With regard to the use of carrier material with capillary-like holding spaces which hold latent heat storage material, reference is also made to PCT/EP98/01956 (WO98/53264), which is incorporated in its entirety into the present application, partly with a view to incorporating features into claims. Moreover, the carrier material may be commercially available packaging fillers, suction agents for chemicals, in particular for oil, fire-retarding agents, viscosity-increasing agents, carrier materials - in particular for chemical waste - and micro-nonwovens or suction mats. In this context, reference is made in particular to the products supplied in different specifications by Rench Chemie GmbH, for example under the protected trade names Rench-Rapid 'R', Rench-Rapid 'G', Perleen 222, Perleen 444, Rapon 5090, Rapon 5092 and Rapon 5093. The high apparent density which is inherent to suitable oil binders results in an additional and significant heat storage effect.

Furthermore, it is preferred for the hygroscopic material to be in the form of flakes, grains or granules, or to be contained as a powder in the latent heat storage material. In particular, it is possible for the hygroscopic material to be disposed on

one or more of the individual support-material bodies. In addition to being disposed on the surface of the individual support-material bodies, it is also conceivable for the hygroscopic material to be disposed in the interior of the individual support-material bodies. In a further preferred embodiment, the individual support-material body and the sheath of the latent heat storage body are disposed spaced-apart by a gas-containing space. This gas-containing space can be used in particular to apply microwave-active moisture from the environment to the latent heat storage material, and may furthermore be provided as a moisture store and/or as an expansion vessel.

Alternatively, or in combination with the hygroscopic material being disposed on an individual support-material body, it is possible for the hygroscopic material to be disposed on a distribution body which extends in two or three dimensions in the latent heat storage body. A distribution body of this nature may have capillary spaces which open up paths to the hygroscopic material for the microwave-active moisture and, as a result, distribute the moisture within the latent heat storage body. In this case, the intention is to split roles, so that the distribution body which has capillary spaces distributes the microwave-active moisture in liquid form inside the latent heat storage body, so that it can be taken up by the hygroscopic material which is preferably likewise disposed in distributed manner thereon. After the moisture, in use, has evaporated and escaped from the hygroscopic material and/or directly from the distribution body with capillary spaces, the hygroscopic material fulfils the role of binding the microwave-active moisture back again as completely as possible in a uniform distribution. If complete rebinding is not possible, for example as a result of vapour having escaped into the environment, the moisture deficit is compensated for as a result of

microwave-active liquid flowing back in through the branching capillaries of the distribution body. Therefore, the form of the capillaries of the distribution body is preferably such that they are aimed at achieving the maximum possible passage of microwave-active liquid, while the capillaries of the hygroscopic material, in order to reinforce the hygroscopic property, are preferably formed or dimensioned in such a way that they also bring about capillary condensation of microwave-active vapour. Furthermore, it is also possible for the distribution body itself to be formed from a hygroscopic material. Furthermore, consideration may be given to the sheath of the latent heat storage body having a closeable opening, by means of which, particularly in the case of a sheath which is impermeable to vapour diffusion, it is possible where necessary to influence a supply or removal of moisture. In a specific configuration, the distribution body with the capillary spaces for the microwave-active liquid extends from the closeable opening in the sheath into the latent heat storage body. An advantageous configuration of the distribution body provides for the capillary spaces contained therein to exert an automatic sucking action only on the microwave-active liquid, but not on the latent heat storage material, thus preventing the capillaries from becoming blocked with latent heat storage material. This may be achieved on the basis of the different viscosities of paraffin-based latent heat storage material and of water, for example by suitably adapting the dimensions of the capillary spaces, or in some other suitable way. In this respect, attention should also be paid to ensuring that the pores in the hygroscopic material are in a suitable form so that they act as capillaries only with regard to the microwave-active moisture. In addition, or as an alternative, it is also possible for the hygroscopic distribution body to be surrounded by a sheath which is

impermeable to the latent heat storage material. As a result of the sheath, latent heat storage material is also prevented from penetrating into pores in the hygroscopic material and blocking these pores. In particular, a construction in which the hygroscopic material extends in the manner of a wick inside the sheath may offer advantages, in which case the sheath may consist, for example, of a film of very small wall thickness. At any rate, the bodies made from hygroscopic material have a self-cleaning action to the extent that, at least with a sheath of latent heat storage material which is not yet sealed against vapour diffusion, they take up water again on their own and melt open again on the next occasion of use.

In further detail, it is also preferred for an additive which leads to a high viscosity to be added to the latent heat storage material. For this additive, it is possible to use a standard agent with thixotropic properties. Even in the heated state, in which the latent heat storage material is usually liquefied, a high viscosity, in the sense of a jelly-like consistency, is still present. Even in the event of a carrier material impregnated with paraffin-based latent heat storage material being unintentionally cut through, latent heat storage material does not run out, or at least does not do so to a significant extent.

It is also possible for the paraffin-based latent heat storage material to contain a proportion of mineral oil and/or polymers and/or elastomers. The rubbers and/or elastomers predominantly result in a higher flexibility, which may also be retained in the solidified state of the latent heat storage material and offers advantages, for example when used for seat cushions or bandages. These materials are preferably present in an amount of less than 5%. If the polymers are not elastomers, they do not increase the flexibility and simply prevent the latent heat storage material from running out, if appropriate as an

additional measure. Highly refined mineral oil is preferably used. By way of example, this may be a mineral oil which is usually referred to as white oil. The polymers are crosslinked polymers produced by copolymerization. The crosslinked polymers form a gel-like structure with the mineral oil by forming a three-dimensional network or by their physical crosslinking (nodular structure). These gels have a high flexibility combined with simultaneous stability when subjected to mechanical forces. The paraffin is included in this structure in the liquid state. When the phase change, the crystallization, takes place, the paraffin crystals which form are surrounded by the gel structure, resulting in a flexible overall mixture.

In one possible application, a latent heat storage material which contains paraffin with a melting temperature of 50° Celsius and a copolymer with a melting temperature of 120° Celsius can be heated to a temperature of 125° Celsius, so that firstly homogeneous mixing of the two components is achieved, and the low-viscosity mixture can be taken up by the carrier material on account of the capillary forces acting therein until it is completely saturated. During subsequent cooling, the paraffin crystals formed are surrounded by the copolymer. In an example of a conceivable upper operating temperature of the latent heat storage body of 80° Celsius, only the paraffin fraction, but not the copolymer, is liquefied. This has the advantageous effect that the paraffin cannot escape from the copolymer and remains in the carrier material together with the latter. It is pertinent to the invention that the desired paraffin retention capacity in the latent heat storage body when using the carrier material described above can be achieved even when the copolymer forms less than 5% by mass of the latent heat storage material.

Examples of polymers used are styrene/butadiene/styrene (SBS), styrene/isoprene/styrene

(SIS) or styrene/ethylene/butylene/styrene (S-EB-S). In particular, an agent known under the trade mark "KRATON G", marketed by Shell Chemicals, is used. Since "KRATON G" contains hydrogenated copolymers, this agent has a high thermal stability and is therefore eminently suitable for the application proposed here. The "KRATON G" rubbers are known to be compatible with paraffin and naphthene oils. The triblock copolymers are said to be able to take up more than twenty times their weight in oil, so that it is possible to produce products whose consistency - depending on the grade and concentration of the rubber - can be varied within broad limits. Optionally mixed diblock polymers contain the AB type, for example styrene-ethylene propylene (S-EP) and styrene/isoprene (SI). The ABA structure of Kraton rubber molecules contains polystyrene end blocks and elastomeric middle blocks. Furthermore, however, it is also possible to use other known Kraton variations. This block copolymer is preferably suitable as a thickening agent for increasing the viscosity and/or as a flexibilizing agent for increasing the elasticity. Kraton G is a thermoplastic plastics material; a number of types of copolymers of the Kraton G series exist, these copolymers differing in their structure. The Kraton rubber polymers have elastomeric properties and an unusual combination of a high strength and a low viscosity. Moreover, they have a molecular structure comprising linear diblock, triblock and radial copolymers, the molar weight of which varies and which have a differing ratio of styrene content to elastomer content. Of the known Kraton G grades, it is preferably possible to use the grades known as G 1650, G 1651 and G 1654. Each molecule of the Kraton rubber may comprise block segments of styrene monomer units and rubber monomer and/or comonomer units.

Furthermore, it is also possible to use copolymers, such as for example HDPE (high-density

polyethylene), PP (polypropylene) or HDPP (high-density polypropylene).

Furthermore, it is possible to add a mixture which at least contains various copolymers selected from the group consisting of diblock copolymers, triblock copolymers, radial block copolymers and multiblock copolymers, to the paraffin-based latent heat storage material, the mixture preferably containing at least one diblock copolymer and at least one triblock copolymer, while the diblock copolymer and the triblock copolymer may contain segments comprising styrene monomer units and rubber monomer units.

It is relevant that the abovementioned additives on the one hand be distributed homogeneously within the paraffin or be penetrated homogeneously by the paraffin and, secondly, that there is no chemical interaction between the additives and the paraffin. Furthermore, it is particularly important for the selection to be made in such a way that there are virtually no differences in density between the additives and the paraffin, so that as a result it is also impossible for any physical segregation to take place.

The second part of the object is achieved by ~~the provision of a production method having the features according to Claim 22, in respect of which advantageous procedures are specified in subclaims 23 to 28~~.

To this end, ~~Claim 22~~ the invention provides a method for producing a latent heat storage body with paraffin-based latent heat storage material held in a carrier material which has holding spaces, in which method the latent heat storage material is liquefied and is supplied in liquefied form to automatically sucking, capillary-like holding spaces in the carrier material, in which method it is provided that the liquefied latent heat storage material is supplied to a plurality of individual support-material bodies of a

latent heat storage body. This supplying may, for example, be effected by the carrier material in the liquefied latent heat storage material being poured over the carrier material. Particularly for the production of relatively large latent heat storage bodies, it is recommended for individual support-material bodies, which are prefabricated in relatively large numbers and in dimensions which are smaller than the latent heat storage body, to be impregnated with latent heat storage material. Compared to the known, reverse procedure, in which firstly a cohesive support-material body of any size is impregnated with latent heat storage material and partial latent heat storage bodies are only cut from the support-material body in the impregnated state, the method according to the invention results in quicker and therefore less expensive impregnation of the carrier material. As in the known method using the reverse sequence of operations, it is possible to use numerous relatively small partial or individual bodies part bodies of virtually any desired shape and/or size for a latent heat storage body, so that the impregnated carrier material provides virtually unlimited options for forming the latent heat storage body. Furthermore, the method according to the invention may particularly advantageously also be used for producing a microwave-active latent heat storage body with a paraffin-based latent heat storage material by applying a hygroscopic material to the surface of the carrier material. In practice, to do this the procedure may be such that the paraffin-based latent heat storage material to be used is initially worked up so as to form a molten material, the viscosity of which can be adjusted, and preferably thereby increased, by the addition of additives, for example of Kraton, in a concentration of up to ten percent, preferably of up to two percent. In a subsequent method step, this molten material is supplied to automatically sucking,

capillary holding spaces in the individual support-material bodies, for example by dipping the latter into the molten material or pouring the molten material over the individual latent heat storage bodies, with the additional option of assisting the sucking action by controlling the temperature in a specific way and/or by supplying mechanical energy, for example by agitation. In a further method step, the hygroscopic material can then be applied to the surface of the carrier material. To do this, it is preferable to add a hygroscopic material which is in the form of grains and/or granules and/or flakes and/or powder to the impregnated individual support-material bodies and to achieve intimate mixing, for example by kneading or stirring, as a result of which the hygroscopic material covers the surface of the individual support-material bodies as uniformly as possible. In this case, it has proven advantageous that, particularly given complete impregnation, there is a layer of molten paraffin-based latent heat storage material on the partial support-material elements, which layer forms again during the cooling process and to which, in particular in the molten state, hygroscopic material adheres particularly well, thus simplifying its homogeneous distribution. As a modification of the procedure described, the hygroscopic material may also be applied to the individual support-material bodies before they are impregnated with latent heat storage material. Particularly in the case of a hygroscopic material in powder form, this makes it possible for this material to enter into the holding spaces in the carrier material together with the latent heat storage material when the latter is sucked in, so that microwave activation also takes place in the interior of the individual support-material bodies. From this, it becomes clear that the proposed use of individual support-material bodies of preferably small dimensions by the method according to the invention in order to

suck up latent heat storage material additionally offers particular advantages for the production of a latent heat storage body which is microwave-activated by means of hygroscopic material. If microwave-active properties are not required, it is, of course, possible to dispense with the addition of the hygroscopic material for producing a latent heat storage body with a paraffin-based latent heat storage material using the method according to the invention, although the advantages of the abovementioned production technology over known production methods for latent heat storage bodies are maintained as a result of the latent heat storage material being sucked into individual support-material bodies of preferably small dimensions and therefore relatively large numbers.

Furthermore, it has proven suitable for commercially available oil binders to be used as individual support-material bodies, in particular the products supplied by Rench Chemie GmbH under the brand names Rench-Rapid R, Rench-Rapid G, Perleen 222, Perleen 444, Rapon 5090, Rapon 5092 and Rapon 5093. If an oil binder in grain form is used to suck up the latent heat storage material which has been prepared to form a high-viscosity molten material, the result is a bed of spheres with pulverulent fractions, in which the latent heat storage material is so strongly bound in the individual suction elements or individual latent heat storage bodies that it does not escape even at temperatures which are 20 to 30° above the melting point of paraffin. In this case too, a shiny layer of molten paraffin forms on the suction elements, and this layer forms once again during the cooling process, making an adhesion surface for pulverulent elements of the microwave-active, hygroscopic material. Until after the cooling process, this form of the bed remains freely mobile internally, i.e. it does not become a hard mass, this mobility being desirable in particular for heat cushions. Furthermore, other materials with

structures which are capable of exerting a sucking action, such as for example fibres made from mineral or ceramic materials, organic materials, such as cotton or wool, glass, phenolic resins, plastics, in all the forms in which they can be processed, such as spinning, foaming, granulating, pulverizing, braiding, weaving, etc., can be used as carrier material for sucking up the latent heat storage material. Therefore, the carrier material can be used, for example, as a material in the form of grains and/or granules and/or flakes. Furthermore, it may also be in the form of platelets of a desired strength or in the form of a nonwoven. Furthermore, the method according to the invention may also be used to obtain additional features of ~~a~~ the latent heat storage body of the invention ~~which are mentioned in Claims 1 to 21 or the associated description~~. It also follows from the above description of the production method that a latent heat storage body according to the invention may contain any desired combination, with regard to its components, of the materials proposed for the production method in the specifications which are in each case taken into consideration or are similar.

To achieve the further part of the object ~~according to Claim 29,~~ the invention proposes a method for producing a latent heat storage body with paraffin-based latent heat storage material held in a carrier material which has holding spaces, in which method the latent heat storage material is liquefied and is supplied in liquefied form to automatically sucking, capillary-like holding spaces in the carrier material, in which method it is provided that a hygroscopic material is supplied to a surface of the carrier material. Accordingly, to produce a latent heat storage body, as an alternative to a plurality of individual support-material bodies it is also possible to use a cohesive carrier material. One example of a possible application of this method is the production

of latent heat storage bodies of small dimensions or layer thicknesses and/or of simple geometric form, in which it is possible both to make up a cohesive carrier material without problems and also for this material to be fully impregnated within sufficiently short periods of time.

The invention also relates to a method for heating a solid or liquid heat storage material which on its own cannot be heated by microwave beams or can be heated to a lesser extent than water, and to a heat storage device having a solid or liquid heat storage material which on its own cannot be heated by microwave radiation or can be heated to a lesser extent than water.

Because of the possible time and energy savings compared to heating techniques which were previously customary, heating liquids and solids by microwave radiation has gained increasing importance in recent years. Microwave radiation (microwaves for short) generally involves electromagnetic waves in a frequency range between 1 GHz and 1 THz, corresponding to a wavelength range of between about 0.3 mm and 30 cm. One use of microwave radiation which has by now become very widespread is the heating of foodstuffs in a microwave oven in which energy is extracted by the foodstuffs which have been placed in the oven from the microwave field at frequencies between 2.425 and 2.475 GHz as a result of dielectric losses, leading to the foodstuffs being heated. In industrial applications, a frequency of 5.8 GHz is also in widespread use. On account of the possible time and energy savings involved in microwave heating, it is desirable for a large number of liquids and solids other than foodstuffs to be warmed or heated by microwave radiation. However, of the materials which come under consideration for this heating, many are not inherently heated in a microwave field, and many further materials are only heated to a much lesser extent or more slowly than water. Where, in the latter

group, heating is so weak or slow as to be unacceptable for industrial applications or in domestic use, the corresponding materials are grouped together with the materials which inherently cannot be heated at all by microwave radiation to form the category of so-called "microwave-passive" materials. The group of "microwave-passive" materials also includes those which on their own can be heated to a considerably lesser extent than water by microwave radiation, water being one of the strongly microwave-active materials. For this reason, the high water content of many foodstuffs means that they also belong to the group of "microwave-active" materials which on their own can be heated by microwave beams to an extent or within a period which is technically useful. A particular drawback is that a range of packaging materials, in particular based on paper, wood and plastics, which are frequently also used for foodstuffs, and in addition a large number of predominantly organic liquids on their own cannot be heated by microwave radiation or can only be heated to a considerably lesser extent than water by such radiation. Particularly in the fast-food sector, the packaging material for foodstuffs, in addition to having a protective function, also has the function of keeping the food hot during transport. However, if the heat storage material used for the packaging cannot on its own also be heated by microwave radiation along with the foodstuffs during the heating of the foodstuffs, the foodstuffs lose some of their heat as a result of subsequent thermal conduction to the packaging which is at a lower temperature.

In view of the above, it also counts as an object of the invention to provide a method for heating a heat storage material which, in the context of the invention, is microwave-passive, by microwave radiation, in such a manner that it is advantageous for use, and also a heat storage device which is suitable for this purpose. In this context, a heat storage

material is in principle understood as meaning any material which is able to store heat at least for a short time and to a limited extent.

The first part of the object in this respect is achieved wherein ~~by the method specified in Claim 31, advantageous procedures for this method being specified in Claims 32-37 which are dependent on Claim 31. With regard to the heat storage device, the object set is achieved by the subject matter of Claim 38.~~

~~According to Claim 31, to achieve the object,~~ it is provided that, a hygroscopic material is added to the heat storage material for heat exchange with the heat storage material in a quantitative proportion according to which, starting from a moisture equilibrium of the hygroscopic material at 50% relative atmospheric humidity and 20°C, an amount of 500 g of the heat storage material is heated by at least 50°C starting from 20°C when exposed to microwave radiation with a power of 400-600 watts over a period of from 2-10 min, and that irradiation of the hygroscopic material with microwave radiation is effected under corresponding conditions. By way of example, in this respect, consideration is given to using a domestic microwave oven, into whose cooking chamber the heat storage material and the hygroscopic material which has been added to it for heat exchange can be introduced. Alternatively, it is possible to allow the microwave radiation to act on the hygroscopic material in some other way. The hygroscopic material has a pronounced ability to take up moisture from its environment and bind this moisture to itself. In particular, it is also able to remove the moisture contained in the air in the chamber, in the form of water vapour, under standard conditions and to take up this moisture. Furthermore, it is also possible to promote the uptake of water by increasing the water vapour content in the air. In addition, water which is present in liquid form is also taken up by the hygroscopic material within a very

short time, until a saturated state is reached. The water which is stored in the hygroscopic material itself represents a very microwave-active liquid in the sense of the invention, so that when placed in a microwave field the water is heated up very quickly and intensively, and so is the hygroscopic material. The heat storage material, which by contrast to this is microwave-passive, on the other hand, is not heated or is heated to only an insignificant extent. On account of the hygroscopic material having been added to the heat storage material, heat exchange then commences, in such a manner that thermal energy is transferred from the heated water or water vapour directly and, after the hygroscopic material has been heated, also from the latter to the heat storage material. The heat transfer may take place as thermal conduction, by convection, by thermal radiation or in any desired combinations of these transfer mechanisms. For heat exchange, it is possible to add the hygroscopic material to the heat storage material, by way of example, by disposing the hygroscopic material on one or more surfaces of the heat storage material. If this is not possible or not desirable, the hygroscopic material may also be disposed in distributed manner at a suitable distance from the heat storage material. In any case, it is advantageous if the hygroscopic material, however it is disposed, has a high ratio of surface area to volume or mass, in order to provide the largest possible heat-exchange surface area for the abovementioned heat transfer mechanisms. Suitable hygroscopic materials for the invention are all those in the broader sense which are able to take up the amount of water required for the proposed method within a relatively short time. Preferably, consideration may be given to the use of calcium chloride, iron chloride, copper sulphate, magnesium chloride, potash and silica gel, while in other applications the use of blotting paper or hygroscopic woven fabrics, nonwovens and the like may

offer advantages. In principle, the method according to the invention can be used to heat all solid or liquid microwave-passive heat storage materials whose introduction into a microwave field is known not to entail danger; for the heat storage material, consideration may be given to any material which has at least a limited ability to store heat for a short time. With a view to the problems set out above, consideration is given in particular to the use of paper-based or cardboard-based, wood-based or plastics-based packaging materials.

In a preferred method of application, a heat storage material which lets through microwave radiation is used. Furthermore, it is preferable to use a hygroscopic material whose hygroscopic property is not changed by heating caused by microwave radiation. This means that the hygroscopic material, even after the method according to the invention has been employed numerous times, still has the unchanged property of taking up moisture from the environment and releasing this moisture to the environment during evaporation caused by heating. The method according to the invention may advantageously be embodied by the hygroscopic material being disposed in sandwich form between two panel-like heat storage elements made from heat storage material, preferably from a solid heat storage material. In this case, two or more of the panel-like heat storage elements may be disposed substantially parallel to one another and the hygroscopic material may be distributed in the corresponding interspaces, resulting in the formation of a multilayer system. In practice, the procedure may be such that firstly the hygroscopic material is disposed on the surface of a heat storage element made from microwave-passive heat storage material, and subsequently a further heat storage element is placed onto the hygroscopic material, whereupon these working steps may be repeated until the desired layer structure

is achieved. Alternatively, or in combination, it is also possible for recesses, for example in the form of holes, grooves, notches or geometrically indeterminate three-dimensional surfaces for holding the hygroscopic material, to be made in the microwave-passive heat storage material or in the heat storage elements formed from this material. It is then possible for the hygroscopic material to be introduced into the recesses and fixed inside them by further heat storage material. By way of example, it is possible to provide a surface of a heat storage element with a ribbed profile, to fill the valleys of this profile with a hygroscopic salt and then to attach a further heat storage element to the filled surface. Furthermore, it is preferable for a panel-like heat storage element to be provided with cavities which extend continuously from a surface of the heat storage element which faces towards the hygroscopic material to a surface of the heat storage element which exchanges moisture with the environment. In particular, consideration is given to forming the cavities by spaced-apart punctures or cuts, for example made with a needle. The cavities also make it possible to use vapour-impermeable, microwave-passive heat storage material, in that they themselves provide flow paths for the desired exchange of vapour with the environment. Furthermore, in the case of vapour-permeable, microwave-passive heat storage material, the cavities still allow the ability of this material to diffuse microwave-active moisture to be improved considerably. Furthermore, it is advantageous if, when carrying out the method according to the invention, capillary-like holding spaces for holding a latent heat storage material, in particular a paraffin-based heat storage material, are provided in a solid heat storage element. With regard to the capillary-like holding spaces, reference is made to PCT/EP98/01956, the disclosure content of which is incorporated into the present application in its

entirety. According to a further preferred application of the method, a heat storage element is formed from poplar wood.

It is known that it is not possible to achieve a fully uniform distribution of the microwave radiation intensity in the interior of the cooking chamber of microwave ovens. This leads to uneven heating of the microwave-active materials contained therein and may, depending on conditions, lead to local overheating and to damage. Therefore, for an advantageous configuration of the method according to the invention, it is proposed for the three-dimensional distribution of the microwave radiation intensity to be made more uniform by a foil which reflects the microwaves in the region where the radiation intensity is high in relative terms. The procedure for this purpose may be such that preliminary tests are used to determine the temperature distribution within a microwave-active material which is spread out substantially flat in the microwave oven, and that the position and distribution of regions which are at relatively high temperatures, corresponding to the regions of relatively high radiation intensity, are marked. Then, in a subsequent step, a foil which reflects the microwaves can be cut out in such a way that its shape corresponds precisely to the surface regions of relatively high radiation intensity. The reflective foil which has been cut out can then preferably be disposed beneath the material to be heated during further usages of the microwave oven. In the present case, therefore, it is possible for the foil which has been cut out to be disposed beneath the hygroscopic material and, if appropriate, in addition beneath the microwave-passive heat storage material. The relatively high-intensity microwave radiation which is incident on the foil is reflected on incidence and is deflected into regions with a lower radiation intensity, so that overall the radiation intensity is made more uniform, leading to more uniform heating of

the microwave-active moisture and therefore of the hygroscopic material and of the heat storage material.

Furthermore, it is proposed for the three-dimensional distribution of the microwave radiation intensity to be made more uniform by a homogenizing mask which reflects and/or diffracts and/or refracts the microwaves, in which case the homogenizing mask may preferably be disposed in the region of relatively high radiation intensity. In the context of the invention, a homogenizing mask is understood as meaning a device which, as a result of its materials properties and/or design features, brings about preferential reflection and/or diffraction and/or refraction of microwave beams in a microwave field. To make the radiation intensity more uniform, it is possible for the homogenizing mask to be disposed inside and/or outside the heat storage material in a microwave field or in a cooking chamber of a microwave oven, it being possible for the homogenizing mask to comprise a plurality of individual parts which may be active on their own or in combination with one another and/or by interacting with internal fittings of the microwave, for example a turntable or even the boundary walls of the cooking chamber. By making the radiation intensity more uniform, the homogenizing mask makes it possible to prevent partial overheating caused by increased microwave radiation concentration, and the mask may consist of different materials. In this context, the dielectric loss factor plays a subordinate role. It is possible for the microwaves which impinge on the body to be heated to be scattered by optical deflection. As a result, excessively high radiation concentrations at individual locations, in particular in the centre of the microwave, where the object to be heated, which is situated on a turntable, for example, is relatively stationary, are avoided. The homogenizing mask primarily utilizes the optical properties of the microwaves in order to achieve deflection and partial

extinction. For this application, it is possible to give consideration to uniform, continuous glass bodies with non-homogeneous compositions of the glass material or glass of a uniform structure with a diverging lens surface (either machined directly into the glass or applied, for example by adhesive bonding). The glass may also be in the form of a bed of pounded glass ("glass crunch") or regular geometric bodies, e.g. spheres, rhombi, pyramids and other suitable bodies or mixtures of such bodies with one another. At the phase boundaries which are formed, the microwaves are deflected in undetermined directions, so that a diffuse wave field is formed. If a plurality or parts made from glass or from another suitable material of this nature are used jointly as a homogenizing mask, it is possible, depending on the distribution of the microwave radiation intensity, which is known from preliminary tests, for example, to achieve a particularly uniform radiation intensity by distributed disposition of the parts in the microwave field or microwave oven, disposition in the region where the radiation intensity is relatively high being preferable effected.

In another variant, it is possible for the homogenizing mask used or provided to be a metal grid. In this case, the extinction and/or deflection and/or diffraction of the microwave beams can be influenced by the selection of mesh size and/or wire thickness and/or material composition of the metal grid. In this context, the percentage of the area covered by the mesh grid with respect to the largest possible free irradiation area of the microwave transmitters within the microwave appliance constitutes a decisive parameter. The blocking effect ("Faraday cage") is controlled by selecting the wire thickness and mesh width. The tighter the mesh of the grid, the stronger the screening effect becomes. In the case of total screening from above, the object to be heated is then

only heated from the sides and from below by the beams reflected inside the microwave appliance. In this case, consideration is also given to introducing a tight-meshed metal grid between the heat storage material and the microwave radiation source, in order to screen the microwave radiation in the principal direction of incidence. Furthermore, it is possible for the two variants of the homogenizing mask explained above to be used in combination with one another, so that it is possible to control the microwave radiation intensity in virtually all regions. In this case, the effects of diffraction, refraction and extinction are combined with one another and can be appropriately combined with one another by materials combinations and arrangements for the particular application. By means of the homogenizing mask, for example, local overheating of a heat cushion which has been introduced into a microwave can be prevented, which would otherwise lead to the cushion being destroyed.

In addition to the abovementioned materials, (glass, metal) and the body shapes specifically mentioned, other expedient configurations of a homogenizing mask are also conceivable. A practical configuration will be based on the desired reflection and/or diffraction and/or refraction properties and on not impairing the operation and reliability of the microwave oven. Furthermore, it is also possible for the homogenizing mask to be used independently of the proposed method for heating a solid or liquid heat storage material which on its own cannot be heated by microwave radiation or can be heated to a lesser extent than water. For this purpose, the homogenizing mask may be provided or used in any desired microwave field, said mask exhibiting the advantageous effects referred to above.

Furthermore, it is also possible for the temperature distribution within the heat storage material and/or the hygroscopic material and/or between

hygroscopic material and heat storage material to be made more uniform by heat-conducting sheets made from material with good thermal conductivity in the transition region between different temperatures. By way of example, sheets made from copper, aluminium or the like, which may be cut into strips or any other suitable shapes, are suitable. The heat-conducting sheets are preferably brought into simultaneous contact, over a large area, with regions at higher and lower temperatures, so that more rapid temperature balancing can be achieved as a result of the good thermal conductivity of these sheets.

To achieve the further part of the object, the a invention ~~independent Claim 40~~ proposes a heat storage device having a solid or liquid heat storage material which on its own cannot be heated by microwave radiation or can be heated to a lesser extent than water, it being provided that the heat storage device contains a hygroscopic material for heat transfer to the heat storage material. In this context, consideration is preferably given to one of the arrangements described above in connection with the method according to the invention for heating a microwave-passive heat storage material. Furthermore, the heat storage device may additionally also have any desired individual features or combinations of features as have likewise been described in connection with the abovementioned method.

The invention also relates to another heat storage device with a solid or liquid heat storage material which on its own cannot be heated by microwave radiation or can be heated to a lesser extent than water, which, with regard to the heating of microwave-passive heat storage material in a microwave field, is based on its own solution idea compared to the heat storage device mentioned above. The starting point for these considerations is that in a number of specific applications, for example medical technology or space travel, it may be of interest to avoid or

reduce as far as possible a vapour phase which is present in the environment. Therefore, under these conditions, for heating microwave-passive material in a microwave field there is a need for a suitable heat storage device in which it is possible to dispense with hygroscopic material and which, if appropriate, can also be combined with the above-described heat storage device with hygroscopic material. Therefore, a further object of the present invention is to specify a heat storage device of the generic type in which, in order to heat a microwave-passive heat storage material in a microwave field, it is possible to dispense with the use of hygroscopic material. In the context of the present invention, a heat storage material is any material which is able to store heat at least for a short time and to a limited extent.

a According features of the invention ~~to claim 49,~~ this object is achieved by a heat storage device with a solid or liquid heat storage material which on its own cannot be heated by microwave radiation or can be heated to a lesser extent than water, it being provided that the heat storage device contains an absorption body with a high dielectric loss index for heat transfer to the heat storage material in a microwave field, and that the length (L, L') of the absorption body in one direction of extent corresponds to at least half the wavelength of microwave radiation selected for supplying energy. In the context of the invention, an absorption body is understood as meaning a body which, on account of its materials properties and the characteristic ratio of its length in at least one direction of extent to the wavelength of the microwave radiation, undergoes preferential heating in a microwave field as a result of dielectric losses. Further details on dielectric losses are to be found, for example, in "Werkstoffkunde [Materials Science], H J Bargel, G Schulze, VDI-Verlag, Düsseldorf, 1994, 6th edition". According to these explanations, dielectric losses arise if a dielectric

has a low conductivity or if it is not of entirely homogeneous structure. In an alternating field (under AC voltage), in the case of non-polar plastics, the time delay in the pole change, and, in the case of polar materials, the vibration of the dipoles which then occurs, leads to further energy losses. These effect a change in the phase shift between current and voltage. If the phase angle in the loss-free capacitor is 90°, the losses of energy in the alternating field result in it being reduced by the angle delta as the complementary angle to 90°. The tangent of this loss angle is referred to as the dielectric loss factor tan delta. This represents the ratio between active current and reactive current and therefore also the ratio between active power (= loss) and reactive power of the capacitor. The dielectric loss index is then:

$\text{Epsilon}'_r = \text{epsilon}_r * \tan \text{delta}$,
Epsilon_r = dielectric constant

This is material-dependent, and its magnitude changes with frequency and temperature, having an increasing effect in particular at high frequencies. Dielectric losses reduce the performance of a capacitor. They are converted into heat. Consequently, plastics materials with a very low dielectric loss index are excellent dielectrics. On the other hand, the internal heating of plastics materials with a higher epsilon_r * tan delta can be utilized deliberately and to good effect industrially, as is the case, for example, in high-frequency welding. The heat storage device proposed in this application uses the preferred heating of an absorption body with a high dielectric loss index to indirectly heat heat storage material in a microwave field. The dielectric loss factor for the various plastics materials is between 10^{-1} and 10^{-4}. Plastics materials which are particularly suitable for heating by high-frequency fields contain heteroatoms

(thus not only hydrogen and carbon atoms, but also, for example, nitrogen or chlorine atoms), which cause permanent dipoles in the molecular structure. Examples of plastics materials with a high tan delta are polyamides (nylon), aminoplastics (melamine) and PVC-P (plasticized PVC). Other materials, e.g. water and certain types of glass, also have high tan delta values.

In connection with the heat storage device according to the invention, it is proposed for the absorption body to be a glass body and/or to contain polyamides and/or aminoplastics and/or PVC-P and/or water. Alternatively, the absorption body may also consist of another material with a dielectric loss index of a suitable level. In particular, it is possible for the dielectric loss index of the absorption body to be between 10^{-1} and 10^{-4}.

In a preferred configuration, the absorption body is provided in the form of a sheet, in which case the sheet length in one direction of extent corresponds to at least half the wavelength of microwave radiation which has been selected to supply energy.

Preferably, consideration is given to the abovementioned direction of extent lying inside the plane of the sheet-like absorption body, for example glass body. When microwave radiation impinges on the sheet-like absorption body, for example glass body, it is absorbed or totally absorbed. The microwaves are refracted in the absorption body, for example glass body, and transmitted in this body until they meet a surface or dislocation, from which they are at least in part reflected in the opposite direction of movement. The reflected microwave radiation is transmitted in the absorption body, for example glass body, until it once again reaches a surface or dislocation, from which it is thrown back in the original direction of movement. In the sheet-like absorption body, for example glass body, the microwave beams are sent to and fro

predominantly along the direction of extent which lies in the plane of the sheet. As it passes through a number of times, the wave energy is converted into thermal energy, leading to desired heating of the absorption body, for example glass body, in the microwave field. In one direction of extent, along which the length of the glass body corresponds to at least half the wavelength of the microwave radiation which has been selected to supply energy, a so-called standing wave is formed, in that the microwave radiation is reflected by surfaces which are opposite one another and are oriented perpendicular to the aforementioned direction of extent, in each case with congruent phases and amplitudes. As a result of the continuous introduction of further microwave beams and resonance phenomena, wave energy becomes concentrated in the standing waves, allowing a correspondingly higher thermal energy yield to be achieved during the energy conversion. If the length of the absorption body, for example glass body, corresponds to at least half the wavelength of the selected microwave radiation even in only one of the directions of extent of the absorption body, for example glass body, which lies in the plane of the sheet, i.e. if at least one one-dimensional standing wave is formed, it is already possible to achieve substantial heating of the absorption body, for example glass body, in the microwave field within short times. By way of example, a radiation frequency of 2.45 GHz gives a wavelength of approximately 12.2 cm, so that an absorption body, for example glass body, of a length of only approximately 6.1 cm is sufficient for formation of a standing wave. Furthermore, it is also possible for the absorption body, for example glass body, also to have a length which corresponds to at least half the wavelength of the selected microwave radiation in other directions of extent, so that standing waves are formed in a plurality of spatial directions and the conversion of

wave energy into thermal energy is still further intensified. Preferably, consideration is given to a configuration of the sheet-like absorption body, for example glass body, in which this body has a substantially planar structure, the length of the absorption body, for example glass body, corresponding to at least half the wavelength of the microwave radiation which has been selected for supplying energy only along a number of directions of extent oriented inside the plane of the sheet. By contrast, the length of the absorption body, for example glass body, in the direction of extent perpendicular to the plane of the sheet may be considerably shorter than half the wavelength of the microwave radiation, in which case it is nevertheless possible to achieve a level of conversion of wave energy into thermal energy which is extremely high and leads to rapid heating of the absorption body, for example glass body. Given a corresponding configuration of the absorption body, for example glass body, as a planar sheet of small thickness, it is possible to achieve a compact arrangement, for example between sheets of microwave-passive heat storage material which are spaced apart from and substantially parallel to one another. A corresponding sandwich-like layer composite may also be composed of a plurality of absorption bodies, for example glass bodies, disposed within one sheet plane and/or substantially parallel to one another, and a correspondingly larger number of sheets of heat storage material. Alternatively, other arrangements of the absorption body, for example glass body, in relation to the heat storage material are also possible. For example, it is possible for the absorption body, for example glass body, to be immersed in a vessel containing a microwave-passive liquid. The relevant factor is that the absorption body, for example glass body, should be heated more rapidly in a microwave field than the microwave-passive heat storage

material. On account of the temperature differences which are established, heat transfer from the absorption body, for example glass body, to the microwave-passive heat storage material begins, so that the heat storage material is also heated. The heat transfer may take place through thermal conduction, convection, thermal radiation or any desired combinations of these transfer mechanisms. The absorption body, for example glass body, may itself be made from extremely simple, inexpensive glass materials, for example from window glass. Even with such a simple absorption body, for example glass body, the conversion of wave energy into thermal energy is promoted by the fact that its length in one or more directions of extent is selected to be equal to an even-numbered multiple of a quarter of the microwave radiation selected to supply energy, in which case the even-numbered multiple must be at least double. It is preferable for the heat storage material to let through microwave radiation. This has the advantageous effect that the entire surface of the absorption body, for example glass body, can be utilized in order to introduce the microwave radiation. An advantageous refinement of the heat storage device according to the invention may be effected by one or more surfaces of the absorption body, for example glass body, being formed to reflect microwave radiation which is incident thereon from the interior of the absorption or glass body. In this case, the "natural" reflection of the microwave radiation from the inner sides of the surfaces of the absorption body, for example glass body, which only captures a certain proportion of the radiation, can be considerably increased by a suitable surface treatment, for example by a coating process. Further advantages of the heat storage device in use can be achieved by at least one surface of the absorption body, for example glass body, having a coating with a temperature-dependent transmission

coefficient for microwave radiation. Preferably, at a temperature of the absorption body, for example glass body, which is initially still low, it is provided that a coating of this nature has a transmission coefficient which allows the microwave radiation to enter into the absorption body, for example glass body, with as little interference as possible and which, as the temperature of the absorption body, for example glass body, rises, makes it more difficult for further microwave radiation to enter. The way in which material layers of this nature act is based on a temperature-dependent structural transformation, for example from amorphous (microwave-transmitting) to crystalline (microwave-reflecting). A coating having a temperature-dependent transmission coefficient for microwave radiation makes it possible to form a self-regulating system, the heating of which is terminated automatically when set parameters are reached, in particular when a desired heating temperature is reached. Since heat transfer from the absorption body, for example glass body, to the microwave-passive heat storage material is only possible in the direction of a temperature drop, the heat storage material is also only heated up to a maximum of that temperature at which the temperature-dependent coating prevents further microwave radiation from penetrating into the absorption body, for example glass body. This has the advantageous effect that even if the radiation intensity and/or duration is unintentionally selected at a high level, it is not possible for the heat storage device and the microwave-passive heat storage material contained therein to be overheated to an unacceptable extent. The application of hygroscopic material to the absorption-body or glass surfaces can also serve to ensure harmonized heating/cooling of the heat storage elements. For example, a simple, and therefore inexpensive, yet effective heat storage

device is achieved by forming the sheet-like glass body as a flat pane of glass, the length of which in at least one direction of extent lying in the plane of the sheet corresponds to at least half the wavelength of the microwave radiation which is selected to supply the energy, by introducing this glass body into the cooking chamber of a microwave oven, and by disposing the microwave-passive heat storage material on the glass body in distributed manner. Alternatively, it is possible to provide a plurality of adjacent glass sheets instead of a single glass sheet.

In a further preferred configuration, the absorption body may be in the form of a film, film packing or bundle of films, for example made from plastics materials. The plastics materials can also be used as a sheath for heating heat-retention elements or heat storage material in microwave appliances. In this case, it may be important or even necessary for the three-dimensional distribution of the microwave radiation intensity to be made more uniform in a heat storage device by a homogenizing mask, in which case the homogenizing mask may have one or more of the features of the homogenizing mask described above. By way of example, it may be a foil which reflects the microwaves and which may preferably be disposed in the region of relatively high radiation intensity in order to make the radiation intensity more uniform.

In addition, or as an alternative, it is also possible for the temperature distribution within the heat storage material and/or between heat storage material and absorption body, for example glass body, to be made more uniform by at least one heat-conducting sheet made from a material with a good thermal conductivity in the transition region between different temperatures. With regard to one possible specific configuration, reference is made to the description of such a configuration in connection with the heat storage device containing a hygroscopic material. As a

supplementary note, it is pointed out that in the heat storage device containing hygroscopic material and in that which has an absorption body, for example glass body, in the form of a sheet, it is also possible to provide one or more heat-conducting sheets whose surfaces reflect and/or diffract and/or refract microwave radiation incident thereon. Therefore, corresponding heat-conducting sheets may be provided in order to make the temperature distribution more uniform both using the route of making the microwave radiation intensity more uniform and by making the thermal energy which has already been stored more uniform.

Furthermore, it is pointed out that the absorption body described above may be provided or used not only in a heat storage device with a solid or liquid heat storage material which on its own cannot be heated by microwave radiation or can be heated to a lesser extent than water, but also, in very general terms, may also be disposed or used in microwave fields, where it leads to the advantageous effects which have been explained.

a BRIEF DESCRIPTION OF THE DRAWINGS

The latent heat storage body according to the invention and heat storage devices according to the invention are explained below, by way of example, with reference to the appended figures of the drawings, in which

Fig. 1 shows a latent heat storage body according to the invention with a closed sheath, in perspective view, partially cut away,

Fig. 2 shows a latent heat storage body according to the invention with a perforated sheath, in a perspective view, partially cut away,

Fig. 3a shows the interior of the latent heat storage body in a regenerated state, as an enlarged excerpt from Figs. 1 and 2,

Fig. 3b the interior of the latent heat storage body following brief heating by microwaves, as an enlarged excerpt from Figs. 1 and 2,

Fig. 3c the interior of the latent heat storage body following prolonged heating by microwaves, as an enlarged excerpt from Figs. 1 and 2,

Fig. 4 a second exemplary embodiment of a latent heat storage body, in a sectional view,

Fig. 5 a third exemplary embodiment of a latent heat storage body with a closeable opening, in a sectional view,

Fig. 6 shows a distribution body which is connected to a water vessel, has capillary spaces and has hygroscopic material applied to it,

Fig. 7 shows a latent heat storage body with a distribution body according to Fig. 6 incorporated therein, in an exploded view,

Fig. 8 shows a distribution body according to Fig. 6 without hygroscopic material applied to it,

Fig. 9 shows a latent heat storage body with a distribution body according to Fig. 8 incorporated therein, in an exploded view,

Fig. 10 shows a microwave-inactive latent heat storage body with a microwave-active enclosure, in a sectional view,

Fig. 11 shows a microwave-inactive latent heat storage body with a microwave-active core,

Fig. 12 shows a sectional view through a first embodiment of a heat storage device with hygroscopic material contained therein and two heat storage elements,

Fig. 13 shows a sectional view through a second embodiment of a heat storage device with hygroscopic material and two in heat storage elements with cavities passing through them,

Fig. 14 shows a sectional view through a third embodiment of a heat storage device with hygroscopic material and one heat storage element,

Fig. 15 shows a sectional view through a heat storage device according to Fig. 14 with an additional outer sheath,

Fig. 16 shows a perspective view of a heat storage device which is formed as a container and has a sheet-like glass body,

Fig. 16a shows a partial section through the container base, along the section line XVI-XVI in Fig. 16, according to a first embodiment,

Fig. 16b shows a partial section through the container base, along the section line XVI-XVI in Fig. 16, according to a second embodiment,

Fig. 17 shows a perspective view of a heat storage device with homogenizing mask in the cooking chamber of a microwave oven, and

Fig. 18 shows a perspective view of a heat storage device with an absorption body and with a second embodiment of a homogenizing mask in the cooking chamber of a microwave oven.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 describes a latent heat storage body 1 according to the invention which is formed as a heat cushion. It has a sheath 2 which is impermeable to vapour diffusion and in the exemplary embodiment shown is formed from a film which is folded to form a double layer along a wrap-around edge 3 and the side edges 4 of which are closed off by welding in such a manner that they are impermeable to vapour diffusion. As can be seen from the partial cutaway in the sheath, the latent heat storage body 1 contains in its interior a number of individual support-material bodies 5 with paraffin-based latent heat storage material 6 held in capillary holding spaces. Furthermore, a hygroscopic material 7 in the form of grains is disposed in uniformly distributed manner over the surfaces of individual support-material bodies, in the interior of which hygroscopic material, water 8 is stored as microwave-active material. For a detailed illustration and description of the functioning, reference is made

at this point to Figures 3a, 3b, 3c and the associated description.

Figure 2 describes a latent heat storage body 1 which differs from that shown in Figure 1 by dint of a sheath 2′ which is permeable to vapour diffusion. It has microperforations comprising openings 9 which are permeable to vapour diffusion and are distributed over the entire area. The size of the openings 9 is ideally selected in such a way that the openings only allow vapour to pass through. However, the bag remains fully useable even if larger openings, for example in the range of up to approximately 0.2 - 0.3 mm, are present. In the "open system" shown in Figure 2, when heating takes place the openings 9 allow vapour to escape into the environment, and when cooling takes place the openings allow the latent heat storage body to be regenerated as required with moisture from the environment. Therefore, with the "open system", compared to the "closed system" illustrated in Figure 1, even small unsealed areas, as may occur during welding, can be disregarded. This results in a considerable reduction in the reject rate during production, which also means that the costs of quality control are reduced. Any excess paraffin can effectively be prevented from blocking diffusion openings, for example by controlled adaptation of the ratio of the diameter of the openings to the surface tension of the paraffin-based latent heat storage material, so that sufficient diffusion openings are always kept clear. In the example shown, the sheath is a plastics film, but it is also possible to use films or foils made from other suitable materials.

The latent heat storage body illustrated in Figures 1 and 2 can be introduced into a microwave which is then set in operation. The power level and duration of action of the microwaves on the product are dependent on the size and thickness, the desired temperature and the intended heating time for the

product. Depending on the parameters selected, the latent heat storage body has been heated sufficiently uniformly, after a few minutes, for all the paraffin contained therein to have melted.

Figure 3a shows an enlarged view of some of the individual support-material bodies 5 contained in the latent heat storage body shown in Figures 1 and 2, with paraffin-based latent heat storage material 6 stored in capillary holding spaces in these bodies; the grains of hygroscopic material 7 which are distributed uniformly on the surfaces of the individual support-material bodies 5 can be seen clearly. In further detail, the dots indicated illustrate that, in a regenerated state of the latent heat storage body 1, the microwave-active water 8 is stored within the grains of hygroscopic material 7.

Starting from this state, Figure 3b describes how, even a short time after the microwave 10 has been switched on, the microwave radiation 11 penetrating into the latent heat storage body 1 leads to evaporation caused by heating and consequently to the water 8, initially in part, escaping from the hygroscopic material 7. The escape of vapour from the hygroscopic material is symbolically represented by the dotted lines of escape. It can readily be seen in Figure 3b that the heated water 8 in vapour form is distributed in cavities 12 between the individual support-material bodies and the hygroscopic material 7. In the process, it passes over the surfaces of the individual support-material bodies 5 or the latent heat storage material 6, which is at a low temperature as a result of being microwave-passive. The microwave radiation 11 penetrating into the latent heat storage body 1 leads to a uniform transfer of heat from the water 8 in vapour form to the paraffin-based heat storage material which is stored in the individual support-material bodies 5 and is initially still at a cold temperature. It can also be seen from Fig. 3b that

the evaporation and the escape of vapour from the hygroscopic material 7 causes the levels of water 8 in the hygroscopic material 7 to be depleted compared to the regenerated state illustrated in Figure 3a. This is indicated by the fact that the dots inside the hygroscopic material 7 are at a greater spacing from one another. Furthermore, the transfer of heat from the heated water 8 in vapour form to the relatively colder surfaces of the individual support-material bodies 5 filled with latent heat storage material 6 causes partial condensation of the water 8 in vapour form, with the result that water droplets 12 are formed on the abovementioned surfaces and heat transfer is promoted still further. As a result of this excellent heat transfer, the paraffin contained in the latent heat storage material 6 is melted quickly and uniformly, and the latent heat storage body is heated uniformly.

As illustrated in Fig. 3c, the water of condensation, which is distributed in extremely fine form and is delimited as droplets 12, is heated again by the incoming microwave radiation, so that ultimately the droplets are vaporized again, a cycle which is repeated a number of times. At the same time, the hygroscopic material 7 is being constantly heated further without vapour condensing thereon. As a result, the water vapour which has formed can take full effect without being prematurely bound back into the hygroscopic material 7. When the heating process has ended and the condensation of the water vapour progresses, the hygroscopic material 7 begins to bind in water 8 again and to prepare this water for the next heating operation.

If excessive water vapour is formed, for example in the event of the microwave being incorrectly operated or as a result of lack of care, the water vapour which has already formed heats up to an ever increasing extent and, in the latent heat storage body

1 illustrated in Figure 2, escapes through the openings 9 of the microperforations, out of the sheath 2′ which is permeable to vapour diffusion, into the environment. Because of the high binding forces, the remaining water 8 is expelled by heating ever more slowly, so that there is no possibility of rapid or explosive evolution of vapour (e.g. on account of retardation of boiling). The water 8 which has escaped into the environment in vapour form through the perforations is compensated for again from the atmospheric humidity through the perforations in the opposite direction by the hygroscopic material 7 on account of diffusion processes. This regeneration process always takes place reproducibly and without hindrance.

If, in the extreme case, the microwave will no longer switch off at all, the water 8 stored in the hygroscopic material 7 is gradually expelled entirely by heating. As soon as the water vapour has been volatilized through the openings into the environment (at temperatures of greater than 100°C), from this time onwards microwave activation is no longer possible and no further heating takes place. If any residual moisture is still present, the risk of fire caused by overheating to an impermissible extent is in addition practically ruled out on account of the water vapour atmosphere and residual water of crystallization which is present, since the temperatures can rise to at most 200°C (temperature at which water of crystallization is heated out of copper sulphate) and, secondly, the water which is present (including in vapour form) serves to "swallow" the ignition energy. During subsequent cooling, the hygroscopic material 7 once again loads up with water 8 from the atmospheric humidity, and after some time (which depends on the atmospheric humidity and the temperature), the concentration deficit of water 8 which arose during heating is compensated for once again, and the latent heat storage body has automatically regenerated itself.

The principle described in Figures 3a, 3b and 3c can also be extended, for example, to sheets, pastes, mouldings and shaped parts of all kinds. For example, it is also possible to produce heat-retention elements, for example in the foodstuffs sector, which do not firstly have to be heated for a prolonged period in electric or steam ovens, but rather can be prepared for use very quickly in a microwave appliance. The result is a lower energy consumption and, furthermore, lower holding capacities being required.

Figure 4 shows a sectional view of a latent heat storage body 13 according to the invention which contains a support-material body 14 in which paraffin-based latent heat storage material 6 is held in capillary holding spaces. In the specific example shown, the support-material body 14 is a fibreboard made from PAP material, reference also being made to the content of PCT/EP98/01956 with regard to further suitable carrier materials. The surface of the support-material body 14 is covered by a film 15 which contains the hygroscopic material 7. The film 15 may itself be formed, for example, from a hygroscopic material 7, but alternatively, or in combination, may also be occupied by or coated with a hygroscopic material 7. As shown in the cross section, the film 15 may be provided over the entire surface of the impregnated support-material body 14, but alternatively may also be disposed only in certain regions of the surface and/or may have openings which are permeable to vapour diffusion. The latent heat storage body 1 illustrated furthermore has a sheath 2, which in the specific example shown is impermeable to vapour diffusion and, by means of spacer elements (not shown), is disposed at a distance from the support-material body with the film 15, so as to form a gas-filled interspace. In the state of the latent heat storage body 13 described in Figure 4, the microwave-active water 8 contained therein, following prior microwave

heating, is still partially in the form of liquid water 8′ stored in the film 15, partially in the form of water 8′′ in the vapour phase which is stored in the gas-filled interspace 16, and partially in the form of liquid water 8′′′ which is condensed out of the vapour phase on the sheath 2 which is impermeable to vapour diffusion. The way in which the "closed system" illustrated operates is based on evaporation of the microwave-active water 8, 8′, 8′′, 8′′′, which is brought about by microwave energy, and subsequent transfer of the heat from the vapour to the microwave-passive and therefore initially colder latent heat storage material 6. For this purpose, the high-energy vapour may bring about heating of the film 15, which for its part transfers the heat to the latent heat storage material 6 stored in the support-material body 14. As an alternative, or in addition, the high-energy vapour may come into direct contact with the latent heat storage material 6 through openings in the film 15 which are permeable to vapour diffusion or via surface regions of the support-material body which are not covered by the film 15, with the result that heat transfer can take place particularly quickly. Furthermore, it is possible for the latent heat storage material 6 to have a modified crystal structure, including with hollow structures, such as for example hollow cones, brought about, for example, by additives, providing flow paths with additional heat-exchange area for the vapour, so that the heat transfer is additionally accelerated. One advantage of the "closed system" illustrated is that even after use in an extremely dry external environment, it regenerates itself quickly and can be used at virtually any time, since the water 8, 8′, 8′′, 8′′′ which is present in the system does not all have to be stored in the hygroscopic material 7 in order for the system to be used. Furthermore, a "closed system" requires only very small amounts of microwave-active water, and for

numerous applications - such as for example heat cushions - even a few drops of water are sufficient for rapid and uniform heating through the evaporation/condensation processes, with equilibrium states being reached very quickly. Moreover, the very small amounts rule out unacceptable expansion and therefore destruction of the microwave-active and microwave-inactive material. As an alternative to the film 15 illustrated in Figure 4, other suitable carrier materials for the hygroscopic material 7 include woven fabrics, knitted fabrics, braided fabrics, fibres and papers made from microwave-active, and, if appropriate, capillary materials, which preferably provide good moisture conduction (for example blotting paper). The hygroscopic material 7 illustrated as a layer in Figure 4 may, for example, be a layer of hygroscopic powder or granules or fine grains.

In Figure 5, there is shown a latent heat storage body 17 which differs from the latent heat storage body 13 shown in Figure 4 in that it has a closeable opening 18. In the specific exemplary embodiment shown, this opening is formed as a tab 19 which is made from film material and can be pivoted about a bending edge 20 of the sheath 2, the sheath being impermeable to vapour diffusion. In the closed position of the opening 18 which is shown in solid lines, in the example illustrated an angled-off tab section 21 engages over the outer side of the sheath 2 on the top side of the latent heat storage body 17, adjoining the opening 18. A connection between the end of the tab and the outer sheath 2 which is able to withstand the vapour pressures which are permitted in operation is created by a large-area closure which has a high load-bearing capacity, for example by a hook-and-loop connection. Together with the top outer surface of the sheath 2, the seal 23 which is integrated into the tab section 21 produces a

connection which is at the same time impermeable to vapour diffusion.

When the opening 18 is closed, the latent heat storage body 17 illustrated in Figure 5, like the latent heat storage body 13 shown in Figure 4, can be used as a "closed system". In this case, however, there is the additional option, by means of a planned configuration of the large-area closure 22, in particular by selecting a suitable closure principle and/or suitable surface dimensions, of providing an additional device protecting against undesirably high vapour pressures in the interior of the latent heat storage body 17. If a suitable limit for the closure force is provided, the large-area closure 22 is automatically opened when a critical vapour pressure is exceeded, so that the vapour escapes into the environment and destruction of the latent heat storage body is prevented. Even if the opening 18 is not opened automatically, after the latent heat storage body has been used the opening can be opened manually, in order to effect a change, in particular an increase, in the amount of microwave-active moisture contained therein. For this purpose, it is also possible for the latent heat storage body 17 to be introduced into a microwave with the opening 18 open, together with an amount of water 8 which is held, for example, in a dish, and for the microwave to be switched on. The water 8 which evaporates from the dish is initially distributed in the vicinity of the latent heat storage body 17 and then passes through its opening 18 into the gas-filled interspace 16, from which it is taken up in a desired quantity by the hygroscopic material 7. Alternatively, it is also possible for the latent heat storage body 17 to be used as an "open system", with the opening 18 continuously open.

In Figure 6, there is shown an arrangement comprising a distribution body 24 and a container 26 which is connected thereto by means of a line 25 and

contains water 8. The line 25 can be blocked or opened for water to flow through by means of a valve 27. As is also shown, grains of hygroscopic material 7 are disposed in distributed manner on the distribution body 24. Furthermore, the distribution body 24 has capillary spaces which open up or form paths to the hygroscopic material 7 in the distribution body. Preferably, it is provided that the capillary spaces are formed in such a manner that they have a capillary action only for the microwave-active water 8, but not for the latent heat storage material 6, which is of a higher viscosity. The distribution body 24 may preferably be in the form of a "capillary network", in which the capillary spaces are connected to one another in the manner of a network. When the valve 27 is open, the water 8 is initially distributed in the distribution body 24 approximately in a star shape starting from the mouth of the line 25, as a result of the capillary action, as illustrated by the arrows. The incoming flow of water 8 only comes to a standstill when there is no longer any concentration gradient in the distribution body. Furthermore, the hygroscopic material 7 disposed on the distribution body 24 takes up water from the capillary spaces of the distribution body 24 until its saturated state has been reached.

Figure 7 describes a latent heat storage body 28 in which an arrangement as shown in Figure 6 is incorporated. In the specific example shown, the distribution body 24 is situated between two individual support-material bodies 29 which are in panel form and are spaced apart from and parallel to one another, containing paraffin-based latent heat storage material 6 held in capillary-like holding spaces. The latent heat storage body 28 is also surrounded by a sheath 2' which is permeable to vapour diffusion and through which the line 25 enters the interior of the latent heat storage body from the vessel 26. In operation of this latent heat storage body, the water 8 stored in

the distribution body and in the hygroscopic material 7 is at least partially vaporized and, in the process, flows along and, at the same time, releases heat to, the latent heat storage material 6 and those surfaces of the panels 29 which face towards the distribution body 24. If, in addition, cavities are provided in the latent heat storage material 6, there is also flow through these cavities, thus accelerating heat transfer. The excess steam escapes into the environment through the openings 9 (not shown in the drawing) in the sheath 2′ which is permeable to vapour diffusion, so that the latent heat storage body 28 gradually loses water 8 while being heated rapidly and uniformly. During the subsequent cooling process, the water 8 in vapour form which is still present in the latent heat storage body is preferably taken up by the hygroscopic material 7. The loss of water which has occurred compared to the starting state can be completely or partially compensated for by opening the valve 27. Compared with the embodiment illustrated, it is also possible for the distribution body 24 itself to have hygroscopic properties, so that it is possible to dispense with providing separate hygroscopic material 7 on the distribution body 24.

The arrangement shown in Figure 8 also differs from that shown in Figure 6 in that there is no hygroscopic material 7 provided on the distribution body in this case. This may be appropriate even if the distribution body itself is not formed from a hygroscopic material 7, but rather - as shown in Figure 9 - hygroscopic material 7 is provided distributed between the adjacent individual support-material bodies 5 with latent heat storage material 6 held therein. In the latent heat storage body 30 shown in Figure 9, the individual support-material bodies 5, which have sucked themselves full of latent heat storage material 6, with the hygroscopic material distributed between them, are

formed into panels 29, between which the distribution body 24 is located. The bodies formed from hygroscopic material 7 are enclosed by a film which is not shown in the drawing but is impermeable to latent heat storage material 6, the film containing a number of tiny holes which are just visible macroscopically. This results, on the one hand, in the hygroscopic material 7 being partitioned from the latent heat storage material 6, so that the latter cannot penetrate into the pores of the hygroscopic material 7. On the other hand, however, it is possible for moisture, in particular water, which can be stored by the hygroscopic material 7 to pass through the tiny holes in the film, so that the hygroscopic material 7 can release moisture to the environment or can take up moisture from the environment. Due to the three-dimensional distribution of the hygroscopic material 7 illustrated, automatic regeneration after heating is assisted by moisture being taken up from the environment through the sheath 2′ which is permeable to vapour diffusion.

In Figure 10, there is illustrated a latent heat storage body 31 in which a continuous layer of hygroscopic material 7 is disposed around a core region of microwave-passive or microwave-active paraffin-based latent heat storage material 6. Because of the microwave-active moisture which is stored in the hygroscopic material 7 and is not shown in the drawing, microwave activation of the latent heat storage body 31 is achieved. As a reversal of this principle, Figure 11 shows a latent heat storage body 32 which has a core region of a hygroscopic material 7 inside the latent heat storage material 6. In the exemplary embodiments illustrated in Figures 10 and 11, it is also possible for the latent heat storage material to be held in capillary holding spaces in a support-material body. Furthermore, consideration is given to using a relatively large number of the latent heat storage bodies illustrated in Figures 10 and 11 as partial

latent heat storage bodies, by holding a plurality of such partial bodies together in a latent heat storage body of larger dimensions.

Figure 12 shows a sectional view of a heat storage device 33 which is formed in a sandwich structure from two heat storage elements 34, 34′ which extend in panel form perpendicular to the plane of the drawing and consist of heat storage material, and a hygroscopic material 7 which is disposed between these heat storage elements 34, 34′ in the form of an interlayer. In the exemplary embodiment illustrated, the cohesion of the layer composite is based on the heat storage device, as shown, being disposed horizontally and on the force of gravity acting perpendicular thereto. As an alternative, cohesion can also be assisted or brought about by fastening means, the selection of which depends on the specific materials used. If the heat storage elements 34, 34′ are, for example, plastics sheets and the hygroscopic material 7 is blotting paper or a hygroscopic nonwoven, cohesion may be brought about by adhesive bonding between the layers in certain areas or over the entire surface. In a variant, it is possible to provide for the heat storage elements 34, 34′ to consist of wood, for example of poplar wood, and for a salt in powder or granular form to be used as the hygroscopic material 7. In this case, it is possible to ensure that the layers are held together by positive connecting elements, for example rivets, which pass through them. In the exemplary embodiment illustrated in Figure 12, the heat storage elements 34, 34′ are formed from a water-impermeable material through which microwave radiation can pass. In a microwave field indicated by microwave beams 11, the microwave beams penetrate into the hygroscopic material 7 through the heat storage elements 34, 34′ and, in a smaller amount corresponding to the area ratio, also via the end faces. The water which is stored in the hygroscopic material 7 and is

not illustrated in the drawing is heated through dielectric losses and transmits this sensible heat to the hygroscopic material 7 and, both directly and indirectly via the hygroscopic material, to the adjoining heat storage elements 34, 34'. For this purpose, the heat storage device illustrated in Fig. 12 has the hygroscopic material disposed in such a way with respect to the heat storage elements or heat storage material that it is specifically ensured that heat is transferred rapidly and without hindrance from the heated water or heated hygroscopic material 7 to the heat storage elements 34, 34', which are still at a lower temperature, by thermal conduction as a result of a large contact area being provided between the individual layers. To a certain degree, the thermal conduction is assisted by convective heat transfer as a result of the water vapour formed during the heating flowing through the hygroscopic material to the surfaces of the heat storage elements 34, 34'. To a certain extent, heat transfer also takes place through heat being dissipated by radiation to the heat storage elements 34, 34' which are at a lower temperature. The evaporation of the water stored in the hygroscopic material 7 caused by microwaves or heating is associated with an increase in the volume of the water. The increase in the volume leads to the pressure of the water vapour in the cavities of the hygroscopic material 7 rising, providing considerable impetus to a flow of water vapour towards the side edges 35, 35' of the heat storage device. The pressure drop leads to water vapour escaping at the side edges 35, 35', as a result of which the level of water vapour in the hygroscopic material 7 temporarily drops. When the heat storage device 33 is subsequently cooled, the hygroscopic material 7 is able to extract atmospheric humidity from the environment via its free surfaces at the side edges 35, 35'. As a result of a corresponding incoming flow 37 of water vapour, the loss of water is

compensated for again, the water which is initially taken up at the edges also passing into the interior of the layer formed from hygroscopic material 7 as a result of diffusion. After a certain time, the hygroscopic material 7 once again has an equilibrium level of microwave-active with moisture with respect to the environment, and the heat storage device 33 has been fully regenerated. It is then available for further heating operations in a microwave field.

Figure 13 describes in a sectional view a heat storage device 38 which differs from the heat storage device 33 shown in Figure 12 in that cavities 39 are formed in the panel-like heat storage elements 34, 34′, which cavities each extend continuously between the inner surface 40, facing towards the hygroscopic material 7, and the outer surface 41, which exchanges moisture with the environment, of the same heat storage element in each case. In this respect, it is to be derived symbolically from the drawing that the cavities 39 form flow paths for water vapour between the hygroscopic material and the environment. The escape 36 of water vapour and the incoming flow 37 of water vapour are in this way intensified and take place in a more uniform distribution along the surface of the hygroscopic material 7. The result is shorter diffusion paths and diffusion times of the water or the microwave-active moisture used in the hygroscopic material 7, so that it is advantageously possible for the heat storage device to be regenerated more quickly after it has been used in a microwave field. The cavities 39 may be provided in a regular or irregular two-dimensional distribution within the plane extending perpendicular to the plane of the drawing.

In Figure 14, there is illustrated in a sectional view a third embodiment of a heat storage device 42 according to the invention, which likewise contains a hygroscopic material 7 disposed suitably for heat transfer to the heat storage material. Unlike the

exemplary embodiments shown in Figures 12 and 13, the heat storage device 42 has only a single heat storage element 34 formed from heat storage material. This element is connected over a large surface area to a layer formed from hygroscopic material 7, in order in this way to allow unimpeded transfer of heat from the water or water vapour which has been heated by microwave radiation 11 and is not shown in the drawing to the heat storage element 34 and from the water or water vapour, via the hygroscopic material 7, to the heat storage element 34. The omission of a second heat storage element 34′ results in a large exposed regeneration surface 43. Accordingly, compared to the heat storage device 38, it is possible for the hygroscopic material to be regenerated even more quickly, and this process can be made still more rapid by, in addition, a controlled increase in the partial pressure of the water vapour in the environment.

In Figure 15, there is shown in a sectional view a fourth embodiment of a heat storage device 44 with hygroscopic material 7 and a heat storage element 34, which differs from the heat storage device 42 shown in Figure 14 through the presence of an additional elastic or rigid, pressure-resistant sheath 45. In the exemplary embodiment illustrated, the sheath 45 is formed to be impermeable to water vapour, so that in the event of heating and vaporization of the water which is not shown in the drawing and is stored in the hygroscopic material 7, brought about by microwave radiation 11, it is not possible for any moisture to be lost from the heat storage device 44. The moisture which escapes from the hygroscopic material 7 when the latter is heated is held by the storage space 46 enclosed between heat storage element 34 and hygroscopic material 7 by the sheath 45, so that the hygroscopic material 7 can be regenerated rapidly from this storage space. Alternatively, it is possible for the sheath 45 to be formed to be permeable to vapour

diffusion, so that it is possible for moisture to be exchanged with the environment. With regard to the selection of materials, and further possible configurations of the sheath 45, reference is made to the further description of these aspects contained in this application.

Figure 16 shows a perspective view of a heat storage device which is provided in the form of a container and has a heat storage material made from poplar wood, which on its own cannot be heated to a significant extent by microwave radiation. The heat storage device 47 is formed from a base element 48, four side elements 49 and a cover element 50. The cover element 50 is pivotably attached to one of the side elements 49 by means of a rotary hinge 51. The dimensions of the heat storage device 47 are selected in such a way that this device can preferably be used as a heat-storing container for a pizza or the like.

Figure 16a uses a partial section through the base element 48, along section line XVI-XVI in Figure 16, to illustrate the structure of this base element in detail. Accordingly, the base element 48 furthermore comprises a continuous, sheet-like glass body 52, the plane of which runs perpendicular to the plane of the drawing and which in the specific example illustrated is formed as a planar pane of glass. Heat storage elements 34, 34′ made from poplar wood are provided adjacent to and in contact with the principal surfaces 52′, 52′′ of the glass body 52, which are parallel to the plane of the sheet. The cohesion between the layers is provided by an adhesive bond which is not shown in the drawing and comprises an adhesive which is permeable to microwave radiation. In a microwave field, the microwave radiation 11, which is illustrated symbolically and not to scale, in particular with regard to its wave form, penetrates into the glass body 52 through the heat storage elements 34, 34′ made from poplar wood. In the process, the microwave radiation 11

is deflected and is shuttled back and forth in the interior of the glass body 52 through repeated reflection at the peripheral edge 53. In the example shown, the illustrated length L of the glass sheet should correspond to at least half the wavelength of the microwave radiation 11 used. Consequently, in the direction of extent of the length L, the conditions required for the formation of a standing wave from the microwave radiation 11 introduced are fulfilled. The standing wave leads to accelerated conversion of wave energy into thermal energy and as a result to the glass body 52 being heated. As a result of the large contact surfaces 52′, 52′′, the heated glass body 52 is associated with the microwave-passive heat storage elements 34, 34′, which are colder in relative terms and are made from poplar wood, in such a manner that heat can flow into the heat storage elements virtually without obstacle. This leads to the desired heating of the microwave-passive heat storage elements in the microwave field. With regard to Figure 16, it is pointed out that the width B of the base element 48 preferably also corresponds to at least half the wavelength of the microwave radiation 11, resulting in the formation of a two-dimensional standing wave in the glass body 52 and even more rapid conversion of wave energy into thermal energy. In the case of the heat storage device 47 shown in Figure 16, consideration is also given to the possibility of the side elements 49 and the cover element 50 having the structure illustrated in the sections 16a or 16b. In Figure 16, the edge sides of the side elements 49 and of the cover element 50 are each provided with a covering 54 which may, for example, be strips of poplar wood or of strips of an adhesive film or foil.

Figure 16b shows in a partial section along line XVI-XVI in Figure 16 a second preferred embodiment of the base element 48 or the side elements 49 and of the cover element 50 of the heat storage device 47.

According to this, it is provided that a multiplicity of sheet-like glass bodies 55 are arranged with their side faces adjoining one another, so that the common principal plane extends perpendicular to the plane of the drawing. As shown in more detail, a coating 56 which has a temperature-dependent transmission coefficient for microwave radiation 11 is in each case applied to the common top side 55′ and the common underside 55′′ of the glass bodies 55. Furthermore, the outer edges 58 and the abutting edges 59 of the glass bodies 55 are made almost completely reflective for microwave radiation incident thereon from the interior of the glass bodies by means of a surface treatment. A heat-conducting sheet made from a thin aluminium foil with a good thermal conductivity is adhesively bonded to each of the principal outer surfaces of the coatings 56. For their part, the principal outer surfaces of the heat-conducting sheets 57 are adhesively bonded over a large area to heat storage elements 34, 34′ made from heat storage material. In the exemplary embodiment illustrated, the heat storage elements 34, 34′ consist of poplar wood and, like the heat-conducting sheets, are permeable to microwave radiation 11. By contrast, it is provided that the coating 56 is permeable to practically all the microwave radiation 11 at a low starting temperature and that, as the temperature rises, there comes about a reduction in permeability. Working on the basis of an arrangement as shown in Figure 16b which has not yet been heated, in a microwave field microwave beams 11 penetrate through the heat storage elements 34, 34′, the heat-conducting sheets 57 and the coatings 56 into the glass bodies 55, with the microwave radiation 11 being deflected. As a result of the reflective nature of the inside peripheral surfaces 58 and abutting edges 59, the microwave beams 11 which have been introduced into the glass bodies 55 are preferably shuttled back and forth in directions which are parallel to the plane of the

sheet. In this case, it is provided that the length L' of the glass bodies 55 in each case corresponds to half the wavelength of the microwave radiation 11, and this may also be the case in the direction of extent extending perpendicular to the plane of the drawing. With regard to the diagrammatically illustrated microwave radiation, it should be noted that this radiation is not to scale in terms of the wavelength and wave amplitude compared to other dimensions shown. In this way, a standing wave is developed in each individual glass body 55 from the microwave radiation 11 introduced. As a result of wave energy being converted into thermal energy in the glass bodies 55, the latter become heated, while the heat storage elements 34, 34' which are made from a microwave-passive heat storage material, in the specific example from poplar wood, do not experience comparable heating. The corresponding temperature drop causes thermal conduction from the glass bodies 55, through the coatings 56 and the heat-conducting sheets 57, into the heat storage elements 34, 34', so that the latter also become heated in the microwave field. If the microwave radiation 11 is emitted by the radiation source with a spatially uneven radiation intensity, the adjacent glass bodies 55 may be heated unevenly. The temperature difference which results from this is also compensated for by the heat-conducting sheets 57 provided. As the heating of the glass bodies 55 increases, the temperature of the coatings 56 also rises. As a reaction to this, the ability of the coatings 56 to allow microwave radiation 11 to pass through them decreases, so that the introduction of this radiation into the glass bodies 55 is reduced and further heating takes place more slowly. Finally, at a desired maximum temperature, the coatings 56 are practically impermeable to microwave radiation 11, so that there is no further heating of the glass bodies 55 and therefore of the heat storage elements 34, 34' made from

microwave-passive material in the microwave field. The result is a self-regulating system which terminates the heating when the set parameters are reached.

Fig. 17 shows a perspective view of a heat storage device in the interior of a cooking chamber 60 of a microwave oven, which is not illustrated in more detail in the drawing. A heat cushion 62 which contains heat storage material is disposed on a turntable 61 in the cooking chamber 60. A microwave emitter 64 is integrated into the ceiling 63 of the cooking chamber 60, emitting microwave radiation 65, 65′ which is symbolically indicated as a wavy line. A comparatively short lateral spacing between the wavy lines of the microwave radiation 65 indicates that a high radiation intensity is achieved in this region of the cooking chamber, while the relatively larger lateral distance between the wavy lines of the microwave radiation 65′ illustrates a correspondingly lower field intensity. The intensity of the microwave radiation 65 is above a desired mean intensity, while the microwave radiation 65′ has a lower intensity than the desired mean intensity. As illustrated in further detail, the heat cushion 62 is situated in the central region of the turntable 61. Microwave radiation 65 of undesirably high intensity impinges as so-called primary radiation, which is illustrated by solid wavy lines, on a partial region of the heat cushion 62 which covers the centre of the turntable. It becomes clear that this partial region of the heat cushion 62 cannot be moved out of the region of undesirably high radiation intensity even as a result of the turntable 61 being rotated in the direction of rotation D, so that in that region there is a risk of the heat cushion 62 being locally overheated and burning through. Furthermore, it can be seen that in its region which lies to the right, as seen in the in the direction of viewing, the heat cushion is exposed to microwave radiation 65′ of lower radiation intensity than desired, so that in that

region the heating will be undesirably low unless the radiation intensity is made more uniform. To provide a remedy to this, in accordance with Fig. 17 a homogenizing mask 66 is provided, which has glass bodies 67, 68, 69, 70 of different shapes. The glass bodies 67 have a pyramid-shape, the glass body 68 is formed as a rhombus, the glass body 69 has the shape of a hemisphere and the glass bodies 70 have an irregular outer contour and are referred to overall as "glass crunch". It can be seen that some of the primary radiation from the microwave radiation 65, 65' impinges on surfaces of the homogenizing mask 66 or the glass bodies 67, 68, 69, 70 which are distributed on the turntable 61 and, from there, following diffraction and/or scattering and/or reflection, is transmitted onwards in another direction as so-called secondary radiation, which is shown as a broken wavy line. It is also possible for the secondary radiation which has been deflected by the homogenizing mask 66 firstly to strike one or more of the walls 71 or the ceiling 63 of the cooking chamber 60 and, from there, to impinge on the heat cushion 62 as secondary radiation. In particular, it can be seen that some of the microwave radiation 65 which has been diverted by the homogenizing mask 66 passes as secondary radiation into a region of the cooking chamber 60 in which otherwise only or predominantly primary radiation from the microwave radiation 65' of undesirably low radiation intensity is present. In this latter region, the secondary radiation from the microwave radiation 65 also impinges on the surface of the heat cushion 62 and brings about additional heating to supplement the primary radiation from the microwave radiation 65' which is incident in that region. Consequently, overall the homogenizing mask 66 makes the radiation intensity in the cooking chamber 60 more uniform and leads to the heat cushion 62 being heated more uniformly. If the radiation intensity distribution in the cooking chamber

60 is known, for example from preliminary tests, it is possible to dispense with a rotary movement of the turntable 61 and for the glass bodies 67 to 70 of the homogenizing mask 66 to be disposed preferably in the region of relatively high radiation intensity of the microwave radiation 65, in order to make the radiation intensity more uniform in a controlled, temporally constant manner. In this case, depending on the particular application, it is possible to optimize the desired heating effects by a controlled selection of glass bodies 67 to 70 of suitable shape, size, thickness and type and by suitably adapting the way in which they are disposed and the heating time, as well as the adjustable heating power of the microwave oven. Instead of the glass bodies mentioned above, it is also possible, by way of example, to use plastics bodies which, compared to glass, have the advantages of flexibility and a low price. If, instead of the heat cushion 62 illustrated, a liquid, for example, is to be heated in the cooking chamber as heat storage material, it is also possible for the homogenizing mask to be disposed inside and/or outside the heat storage material.

Fig. 18 shows a perspective view of a heat storage device which is disposed in a cooking chamber 60 of a microwave oven and has a body 62′ of heat storage material which is to be heated, with a second embodiment of a homogenizing mask 72 and with an absorption body 73 which is wrapped around the body 62′. The body 62′, together with the absorption body 73, which in the present example is in the form of a film, is disposed on a turntable 61. In the example illustrated, the absorption body is a plastics film which is wrapped several times around the body 62′ and is held together on the body by means of a piece of string 74. The plastics material of the absorption body 73 has a high dielectric loss index, and consequently it experiences very intense heating in the microwave

field illustrated comprising the microwave radiation 65, 65′. Due to the wrapping around the body 62′ and the associated direct contact, the heat stored in the absorption body 73 is quickly transferred to the body 62′ predominantly through thermal conduction, so that this body is likewise heated particularly uniformly. A further detail illustrates that the homogenizing mask 72, in its second embodiment, has a tight-meshed wire grid 75 which is disposed in the principal direction of incidence of the primary radiation of the microwave radiation 65, 65′, i.e. between the microwave emitter 64 which is integrated in the ceiling 63 of the cooking chamber 60 and the body 62′. In the example shown, the wire grid 75 is supported by four wire rods 76 of equal length, which extend perpendicular to the wire grid 75, at a distance from the turntable 61 which is such that the body 62′ together with the absorption body 73 finds space beneath the wire grid 75 without coming into contact with the latter. It is essential to the exemplary embodiment illustrated that the dimensions and small mesh width, which brings about a screening action, of the wire grid 75 completely prevent primary radiation of the microwave radiation 65, 65′ from impinging on the heat cushion 62. This prevents excessive local heating of the absorption body 73 and of the body 62′ which has heat storage material contained therein and exchanges heat with the absorption body. Rather, the desired uniform heating is achieved by the primary radiation being deflected by the wire grid 75 of the homogenizing mask 72 and impinging on the absorption body 73 with an intensity which has been made more uniform, preferably in the lateral direction, as secondary radiation, in some cases only after a number of directional changes at walls 71 and/or at the ceiling 63 and/or at further internal fittings in the cooking chamber. As a result, the absorption body is heated uniformly and transfers its uniform heat to the body 62′. The exemplary

embodiments mentioned above make it clear that the homogenizing mask is an essential means for utilizing any microwave fields with differing field intensity distribution, and any desired heating effects can be achieved in particular in conjunction with an absorption body.

The features of the invention which are disclosed in the preceding description, the drawings and the claims may be of importance for realization of the invention both individually and in any desired combination. All features disclosed are pertinent to the invention. The content of the disclosure of the associated/appended priority documents (copy of the prior application) and the contents of PCT/EP93/03346 and of PCT/EP98/01956 are hereby also fully incorporated into the disclosure of the present application.